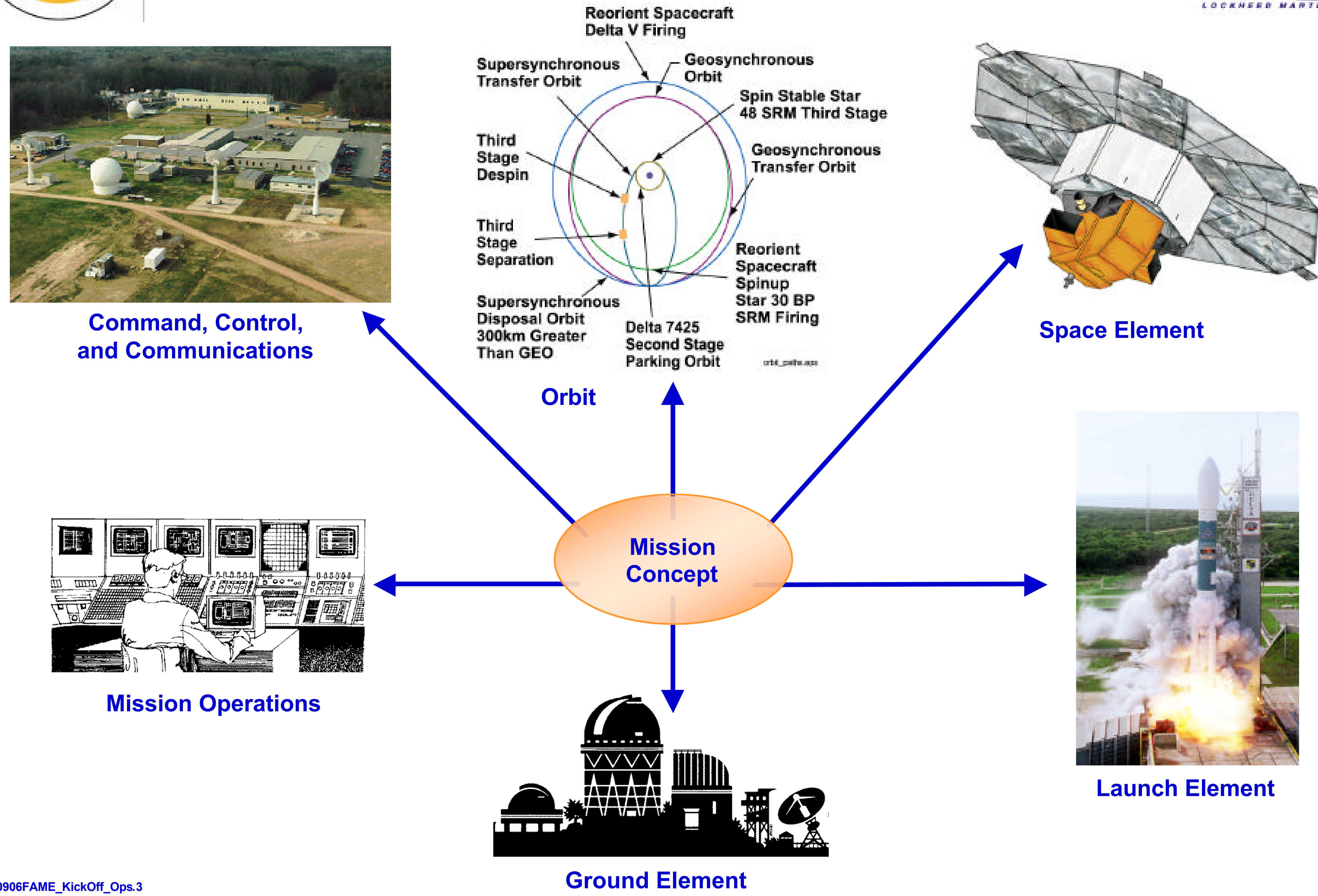
Operations

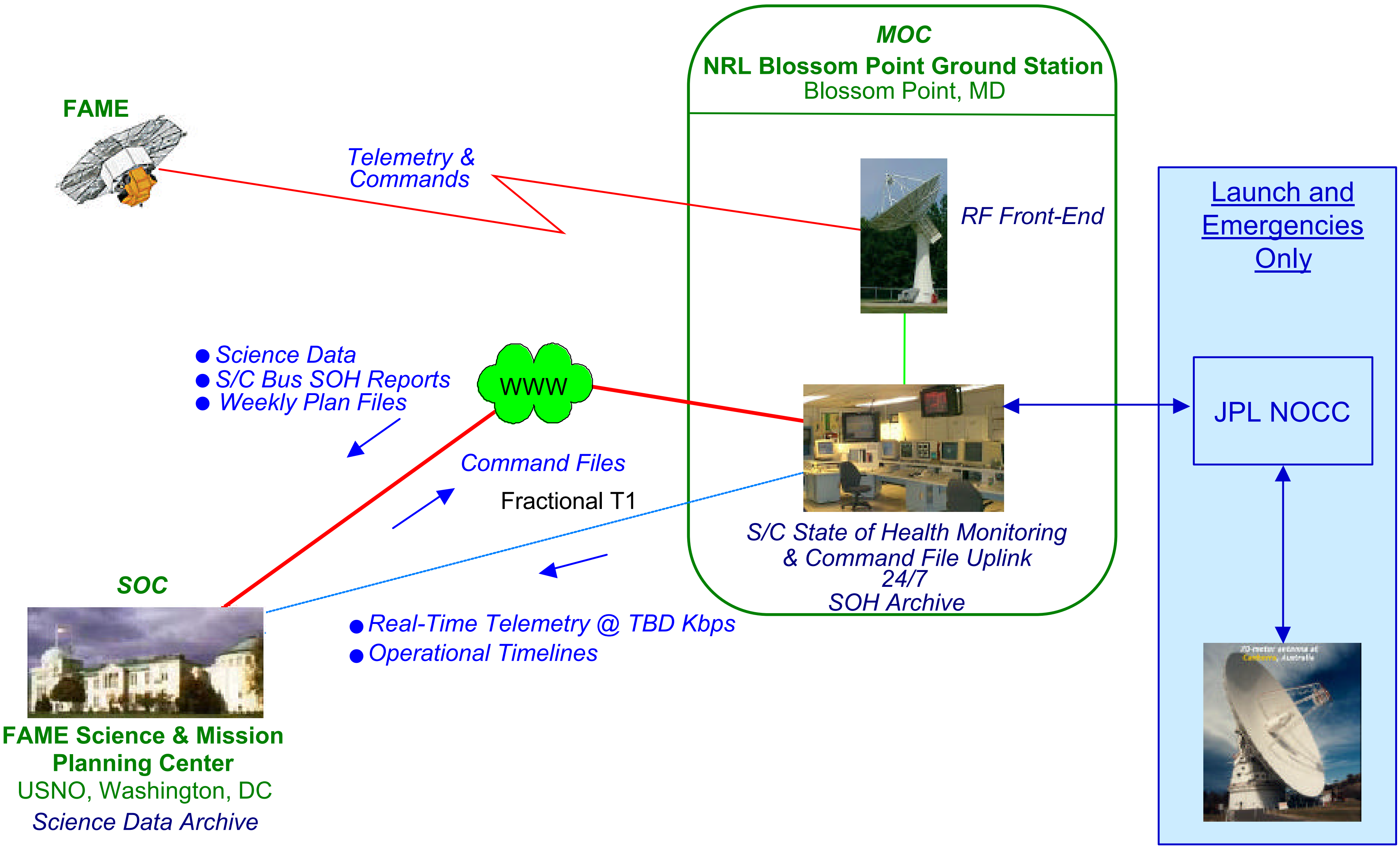
Mission Operations (Blossom Point)

Patty Klein
Ground System Development Lead
NRL
202-767-6636
pklein@ssdd.nrl.navy.mil

Mission Operations Architecture



Operations Concept



Communications Performance Requirements

- **Data Rate: < 500 kbps; < 1 Msps**
- **Bit Error Rate: < 10^{-6}**
- **End-to-End Delay: Minimize; No Specific Latency Requirement**
- **Ranging: Ranging and Range Rate Required**
- **Anti-Jam: No Requirement**
- **Nuclear Scintillation: No Requirement**

Communications
Operational Requirements

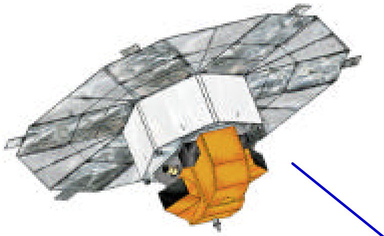
- Security: Unencrypted Uplink and Downlink; Auth Count Implementation
- Standardization: CCSDS-Compliant; Compatible With NASA's Deep Space Network (DSN)
- Backward Compatibility: Compatible With Current BP Architecture
- Access: Single
- Spacecraft Orbit: Elliptical e = 0.0071; Geosynchronous; i = 30°
- Spacecraft Mobility: None, After Completion of Orbital Slot Placement
- User-Terminal Characteristics: Fixed
- Channel Characteristics: Separate Virtual Channels for Bus SOH, Payload SOH, Mission Data

Communications System and Program Constraints

- System Constraints
  - Omni-Directional Spacecraft Antennas
  - Maximum Satellite Transmit Power = 2 W (EOL)
  - Downlink = S-Band
- Program Constraints
  - Use Current Technology
  - Use Non-Development Items to Maximum Extent Practical
  - Stay Within Allocated Budget

Downlink Communications at BP

Geosynchronous

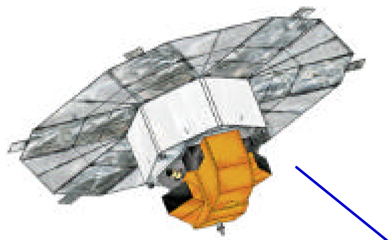


- Modulation Is BPSK Onto Carrier
- Reed-Solomon and Convolutional Coding
- Required Eb/No = 3.0 dB
- Margin > 3 dB

R_d = 409.6 kbps, 800 bps
P_t = 40.0 dBm
BER = 10^{-6}
f = 2.2-2.29 GHz
S = 35786 km
L_{fs} = 191.8 dB
L_{Other} = 6.0 dB

Rcv G/T = 22.3dB/K
Minimum Elev Angle = 5°

Low Rate
Downlink Communications at BP

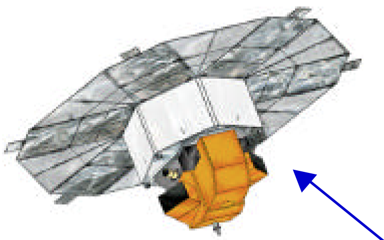


- **Modulation Is BPSK**
- **Reed-Solomon and Convolutional Coding**
- **Required Eb/No = 3.0 dB**
- **Margin > 3 dB**

R_d = 800 bps
P_t = 33.0 dBm
BER = 10^{-6}
f = 2.2-2.29 GHz
S = 35786 km
L_{fs} = 191.8 dB
L_{Other} = 8.8 dB

Rcv G/T = 22.3dB/K
Minimum Elev Angle = 5°

Uplink Communications @ BP

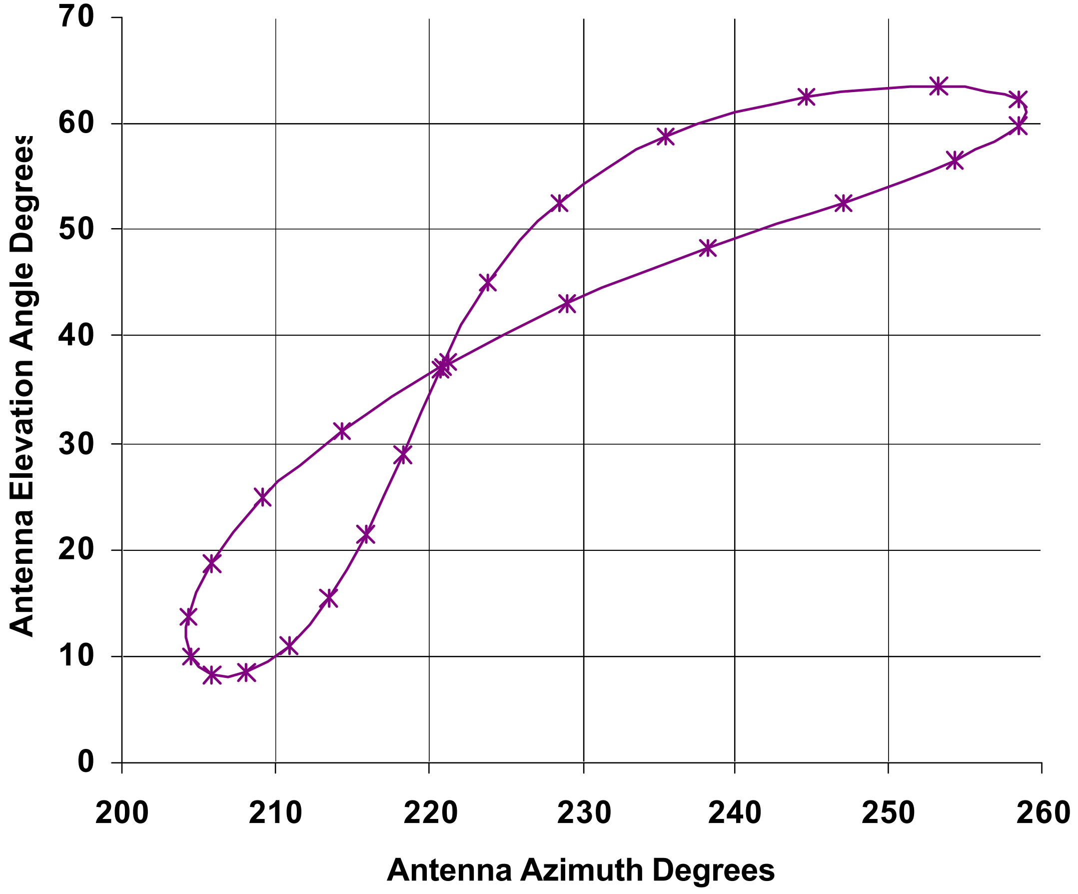


- Modulation Is BPSK
- Margin > 7 dB

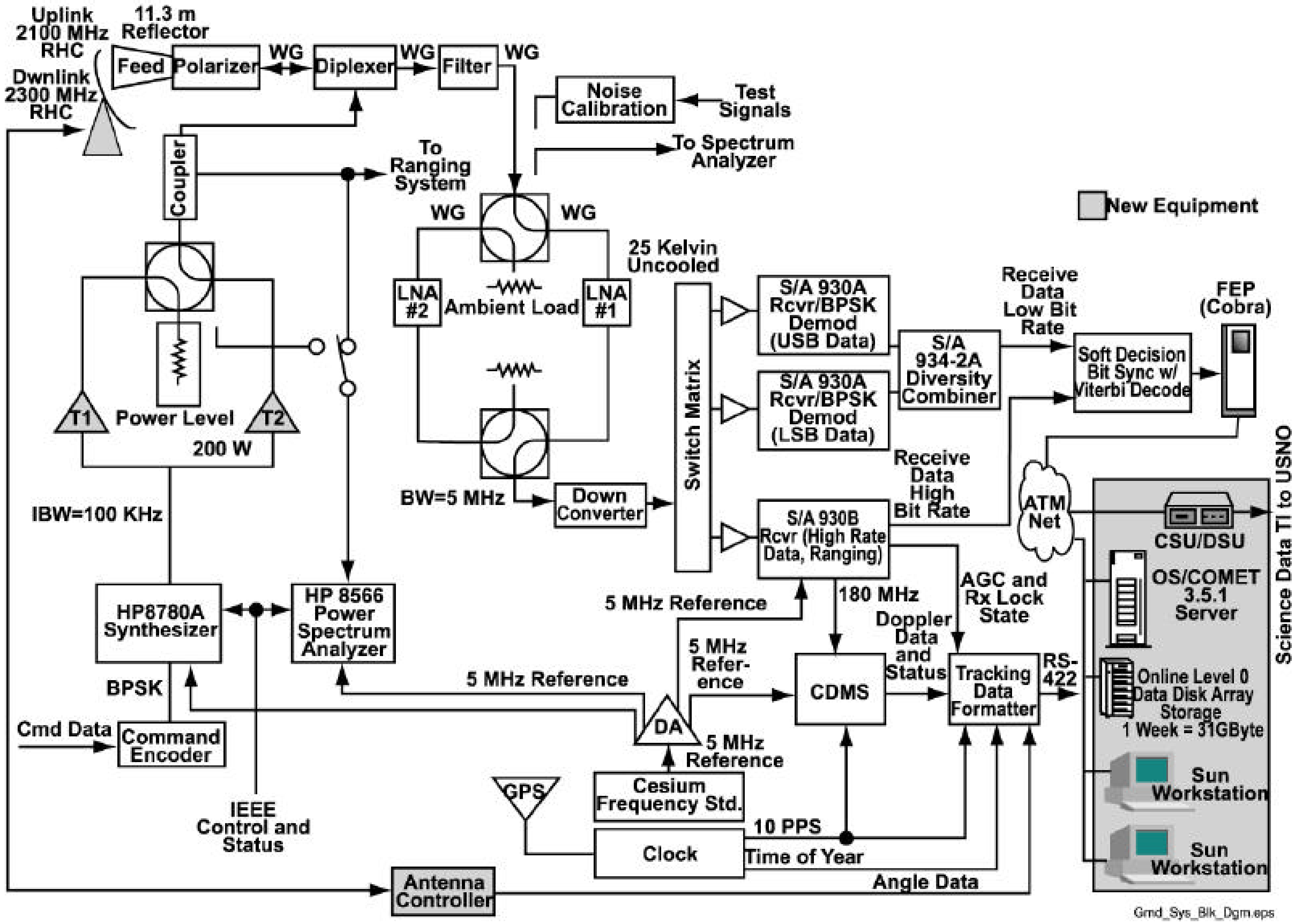
Rcv Sensitivity = -118 dBm

R_u = 2.0 kbps
P_t = 53.0 dBm
f = 2.0-2.1 GHz
S = 35786 km
L_{fs} = 190.3 dB
L_{Other} = 8.8 dB
G = 44.0 dBi

FAME View From BP



BP Ground Data System



Data Archival Volume

Data Rate	500	kbps
Data/Day	5.4	Gbytes
Data/Week	37.8	Gbytes
Data/Month	151.2	Gbytes

Includes Both SOH and Payload Data

Compatibility Testing

- Purpose: Ensure End-to-End Compatibility Conducted Prior to Launch
- Goal: Exercise All Ground System and Mission Operations Elements in Flight Ops or Near-Flight Ops Configuration
- Tests May Include:
  - Pre-Compatibility Test (PCT)
    - Conducted With Transponder at Manufacturer’s Plant Before Acceptance
    - 1 Day
  - Factory Compatibility Test (FCT)
    - Conducted With Integrated S/C at NRL
    - 5 Days
  - End-to-End Test (ETE)
    - Conducted With Integrated S/C at NRL or at Launch Base
    - Could Be Combined With FCT
    - 1 - 5 Days
  - Launch Base Compatibility Test (LBCT)
    - Conducted With Integrated S/C at Launch Base
    - 1/2 Day

Documentation

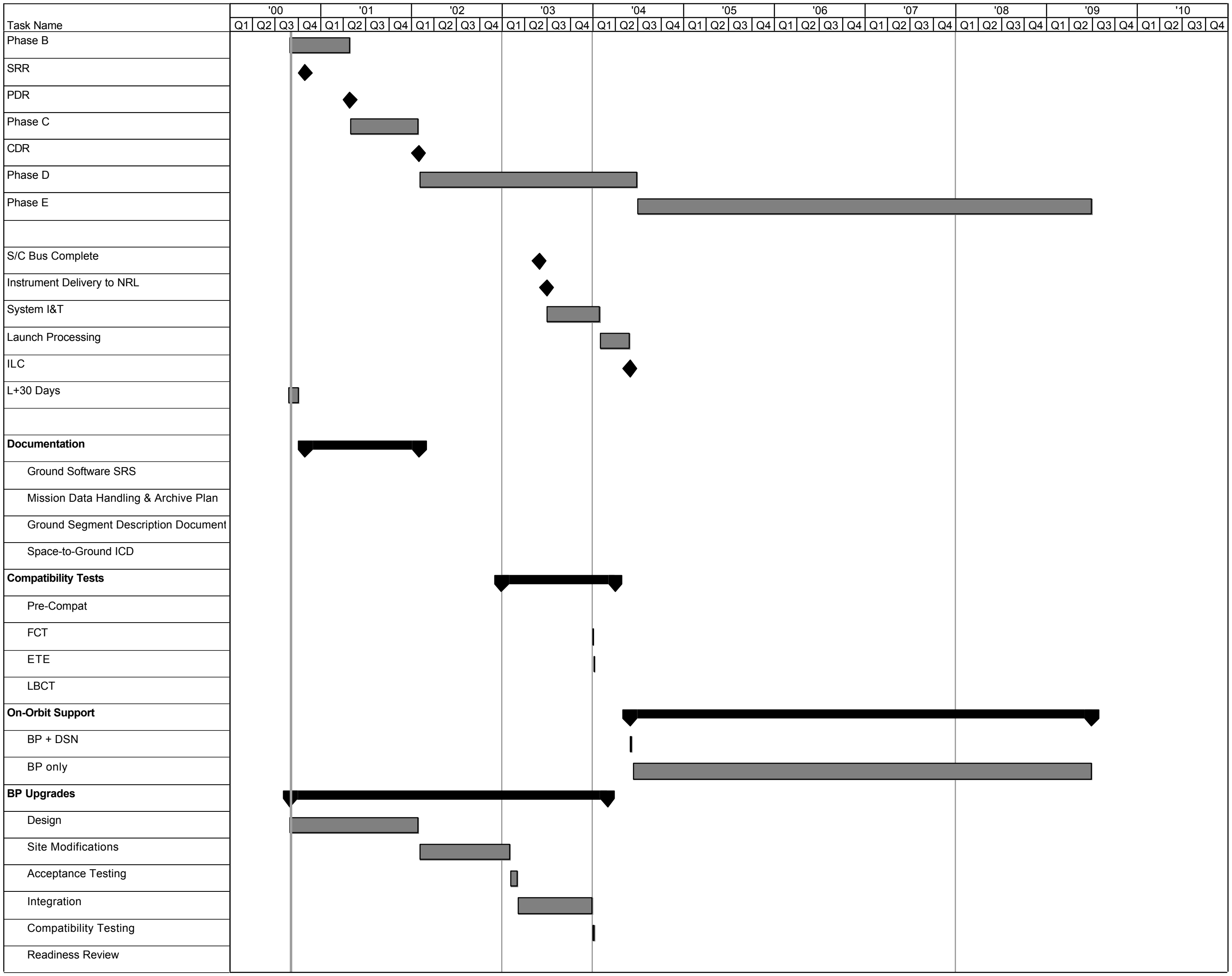
- Ground Software Software Requirements Specification
- Mission Data Handling and Archive Plan
- Ground Segment Description Document [NCST-D-FM016]
- Space to Ground ICD [NCST-ICD-FM003]
- FAME On-Orbit Handbook

Ground System Trades

Function	Considerations/Constraints	Trades
Data Transport and Delivery	Quantity and Rates of Data	Process Telemetry at Ground Station vs Control Center
	Location of Ground System Elements	Choose Type of Communication Links
	Compatibility Between Space and Ground Elements	Design s/c for Compatibility vs Modify Ground System
Mission Control	Complexity of mission	Shared vs Dedicated Resources
	Operations and Maintenance Philosophies	Redundancy vs Allowable System Downtime
Spacecraft Planning and Analysis	Complexity of Spacecraft Bus	Level of Ground Automation
	Orbit	Sophistication of Software
Payload Planning and Analysis	Type of Payload	Level of Onboard Autonomy
	Orbit	Level of Ground Automation
Data Processing	Location of Users (Co-Located or External)	Process Data in MOC vs Dedicated POCC
	Quantity of payload data	Process Data in Real Time vs Post-Pass
Navigation Planning and Analysis	Orbit	Internal vs External Orbit Determination
	Required Knowledge of Orbit	Ground vs Onboard Processing
		Antenna Angle Data Only vs Ranging and Doppler Systems
Archiving	Quantity of Data	Store Raw vs Processed Data
	Compatibility With Existing Recorders	Type of Storage Media
	Duration of Storage	Type of Distribution and Location of Storage/Transportability

Completed

Schedule


Task Name
'00 '01 '02 '03 '04 '05 '06 '07 '08 '09 '10
Q1 Q2 Q3 Q4
Phase B
SRR
PDR
Phase C
CDR
Phase D
Phase E
S/C Bus Complete
Instrument Delivery to NRL
System I&T
Launch Processing
ILC
L+30 Days
Documentation
Ground Software SRS
Mission Data Handling & Archive Plan
Ground Segment Description Document
Space-to-Ground ICD
Compatibility Tests
Pre-Compat
FCT
ETE
LBCT
On-Orbit Support
BP + DSN
BP only
BP Upgrades
Design
Site Modifications
Acceptance Testing
Integration
Compatibility Testing
Readiness Review

Orbit Determination

Alan Hope
OD Lead
NRL
202-404-8595
hope@ssdd.nrl.navy.mil

Requirements

- Velocity Knowledge: 1 cm/sec, Postprocessed
- Use BP as Primary Tracking Site
- Minimize Active Ranging and 2 Way - Range-Rate

Baseline Approach

- Define Tracking Accuracy (Range, Range-Rate)
- Use Covariance Analysis and Monte-Carlo Simulation to Establish Tracking Requirements (ODEAS and Other Internal Tools)
- Recommend Tracking Implementation and Tracking Schedule to Meet Mission Requirements
- Determine Data Arc Length for Best Velocity Fit (4 Day Batch)

Trade Studies

BP 2-Way Range-Rate BP 2-Way Range (10m / 8hr)	2-Way RR Duration and Interval	Velocity Error Avg cm/sec	Velocity Error Max cm/sec
Noise: rr 3s 3 mm/s r 3s 3 m Bias: r 15 m Station Location Bias 1 m	1hr / 8hr	1.05	1.09
Noise: rr 3s 3 mm/s r 3s 3 m Bias: r 15 m Station Location Bias 1 m	1hr / 24 hr	1.12	1.19

Issues

- Range and Range Rate System Installed at BP Must Meet the Noise and Bias Requirements Assumed
- Is the 1 cm/sec Velocity Error an Absulute Maximum Number Over All Times?
- Is the 1 cm/sec Velocity Error a 1s, 2s, 3s Requirement?

Schedule

- FY '01
  - Perform Trade Studies to Refine Tracking Requirements
  - Begin OD Simulations (ODEAS/OCEAN)
  - Establish Software Requirements and Data Formats
- FY '02
  - Work With Science and Ops to Define Data and Refine Requirements
  - Continue OD Sims
  - Start Integration of OCEAN at MGS
  - Establish QC Requirements for OD Ephemeris
- FY '03
  - Continue OD Sims
  - Complete Integration of OCEAN at MGS
  - Conduct Rehearsals
- FY '04
  - Conduct Rehearsals
  - Support Early Operations and System Checkout
  - Perform Daily Ephemeris Generation and Reporting (Through Mission Life)

Science Operations and Data Processing

Ralph Gaume

Mission Operations and Data Analysis Lead

USNO

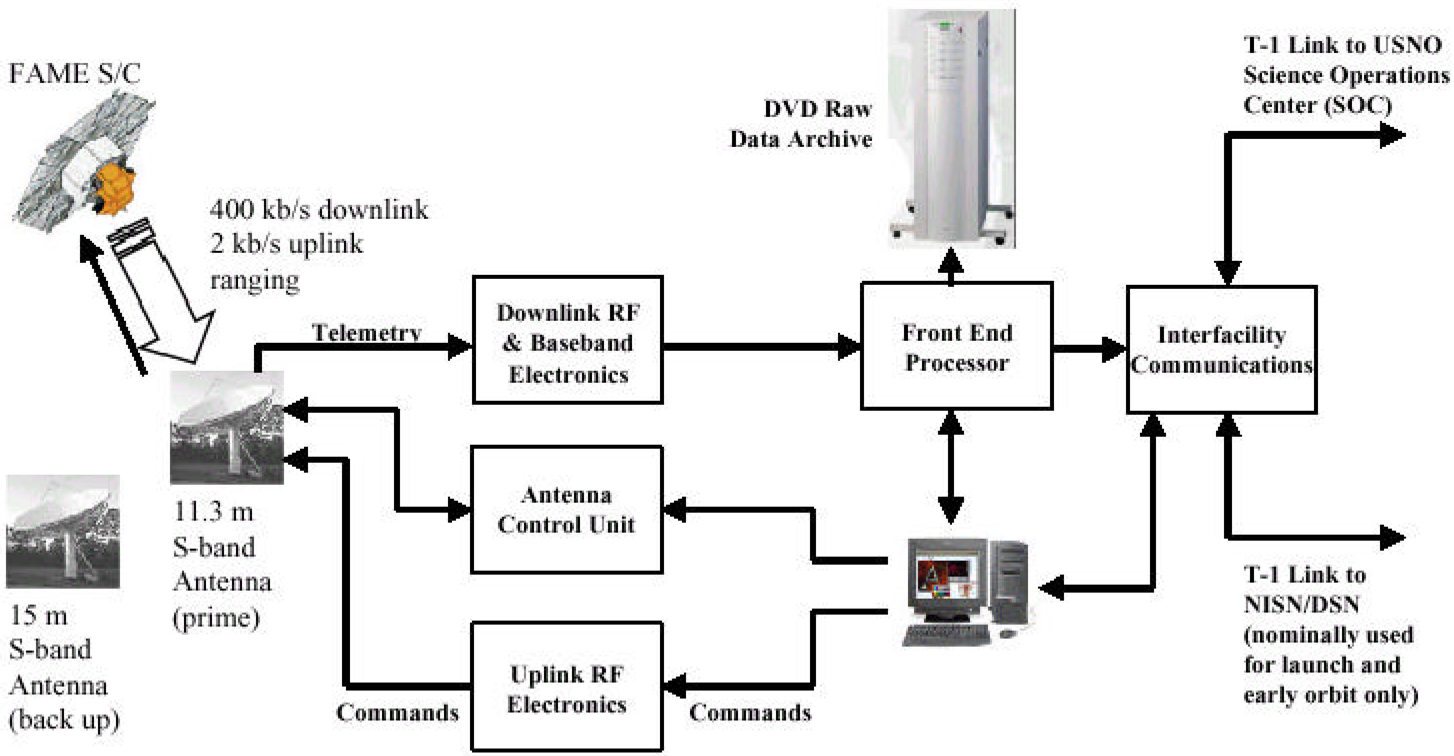
202-762-1519

rgaume@usno.navy.mil

Science Operations

- Definition: Science Operations Begin When the Spacecraft Is Located at GEO, End When Spacecraft Is Moved to a Disposal Orbit
- Goal of Science Operations: Produce Catalog of 40 X 10^6 Stars
  - Initial Catalog at End of NASA Funded Mission (2 1/2 Years)
  - Final Catalog at End of Mission (5 Years)
- Science Operations Center Located at U.S. Naval Observatory, DC
- BP Is Only Ground Site Required for Science Operations
- Attitude Control System Effectively "Disabled", Monitor Only Mode, Spacecraft Precession Driven Primarily by Solar Radiation Pressure

Mission Operations Center (BP)

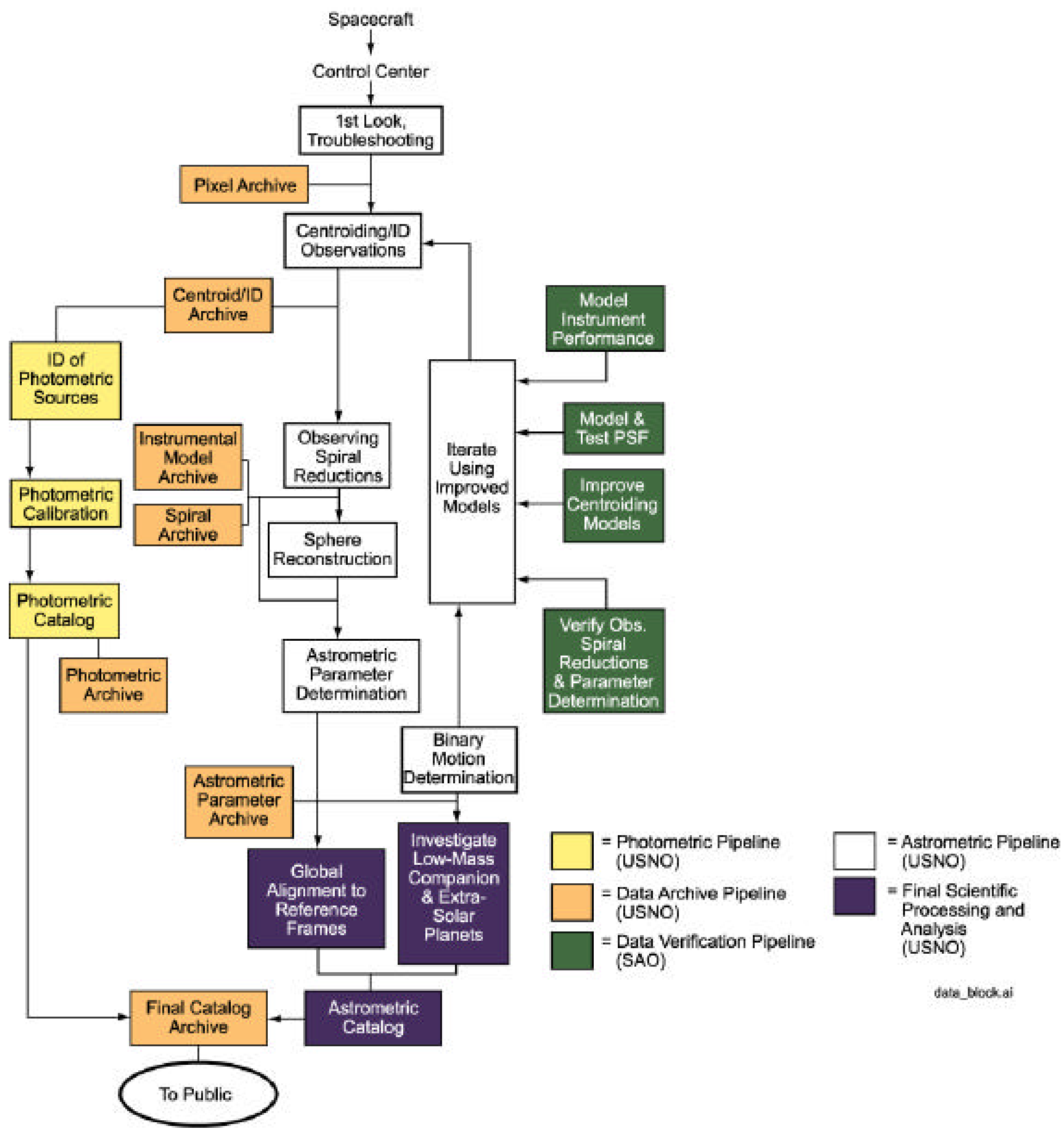


Science Operations Center (USNO DC)

Science Operations

- MOC and SOC Are Connected by Dedicated T1 Link
- Raw Downlink Data Is (Identically) Archived at Both BP and USNO (Most Likely) on DVD: ~ 8 Tby Over 5 yr. SOC Verifies That Archives Are Identical
- Science Data Archives:
  - Centroid: Time, Location, Amplitude of Transit Events
  - Instrumental Model: Satellite Motion & Other Instrumental Parameters
  - Spiral: Positional Data From Each Observation
  - Photometric: Data From Photometric Pipeline
  - Astrometric Parameter: Position, Proper Motions, Parallaxes
- Archive Media Most Likely DVD
  - Final Catalog Most Likely Issued on DVD
- SOC Receives All Spacecraft Telemetry
  - FAME SOH Monitored by Both SOC and MOC
- MOC Operates the Spacecraft Bus, SOC Operates the Instrument, All Communications With Spacecraft Through the MOC
  - SOC Develops & Tests Instrument Tasking Scripts Which Are Transmitted Electronically to MOC for Eventual Spacecraft Upload

Data Flow Diagram



Science Data Processing (1 of 2)

- First Look & Troubleshooting: Spacecraft Data Must Be Immediately Checked After Downlink. Anomalies Must Trigger Recovery Activity
  - Image Detection
  - Image Quality
  - Satellite Attitude
- Centroiding:
  - Postage Stamp Pixel Data Telemetered to the Ground
  - Calibrate for Known Defects and Distortions
  - Centroid Image to 1/350 Pixel
- Observing-spiral Reductions
  - As Spacecraft Rotates & Precesses, CCD Maps an Observing Spiral on the Sky
  - Observing-spiral Reductions Will Characterize Spacecraft Motion and Temporal Changes in Instrumental & Spacecraft Parameters

Science Data Processing (2 of 2)

- Sphere Reconstruction: "Glue" Together the Independent Observing-spirals
  - Use Subset of Stars (Grid Stars); Point-like With Constant Space-velocities
  - Observations Modeled As Variables Expressed As Function of Astrometric Parameters (Position, Proper Motion, & Parallax), Observing-spiral Origins and Orientations, and Global Parameters (Nasties)
  - Iterate Until Observing-spiral and Global Parameters Converge
- Astrometric Parameter Determination: Make Weighted, Least-squares Fit to Observations for All Stars to Produce Astrometric Parameters
  - Examine Residuals for Peculiar Motions. Investigate…
- Global Alignment: FAME Frame Will Be Internally More Precise and Rigid Than Any Existing Celestial Reference Frame
  - However, Global Rotations May Still Exist, So Rotate Fame Frame Into the ICRS/ICRF
  - Observe As Many Quasars As Possible With FAME, and Radio Counterparts Where Possible (VLBA)
  - Observe Radio Stars With FAME and Radio Counterparts (VLBA & VLA-A+)